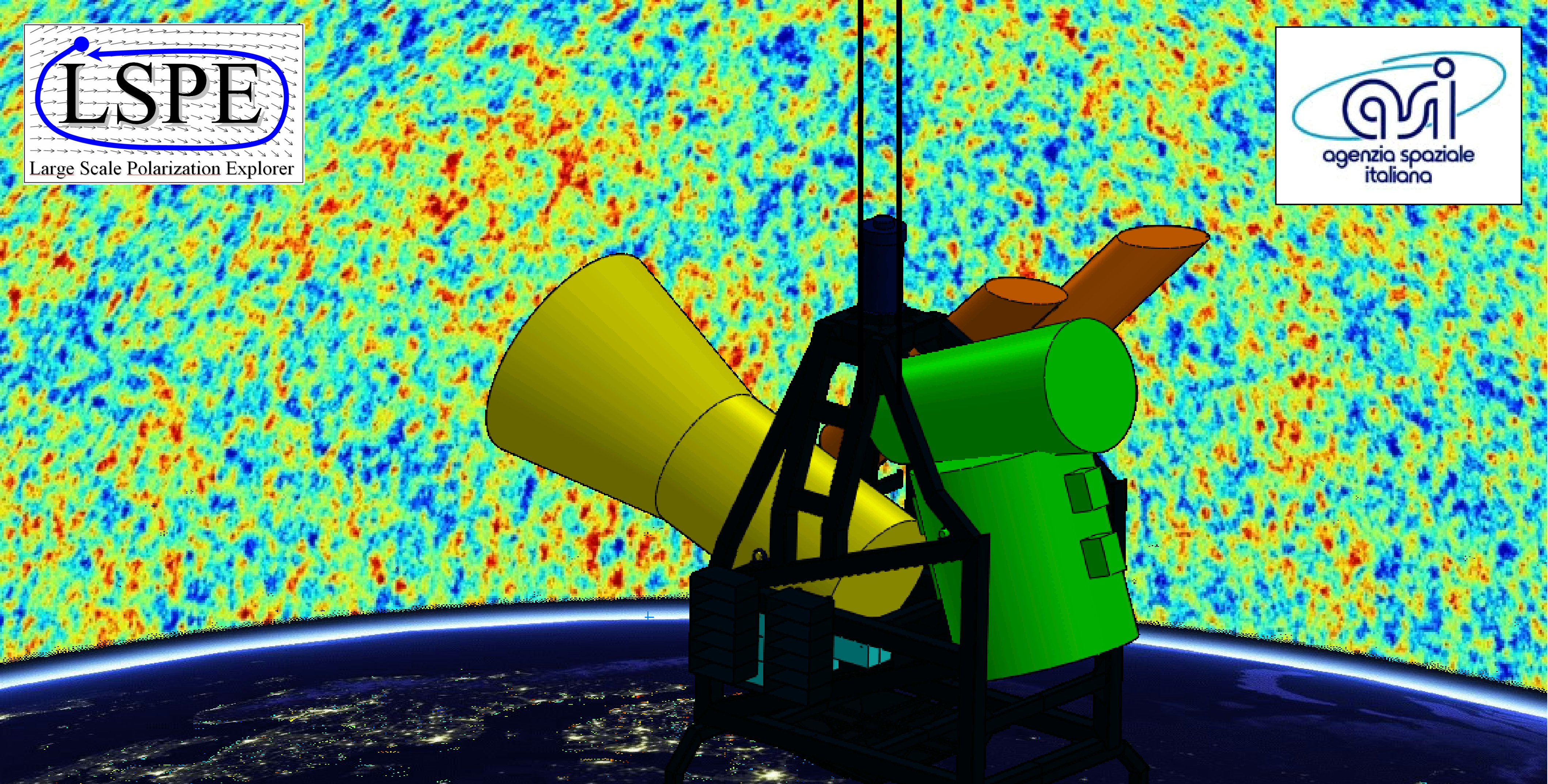


Large Scale Polarization Explorer

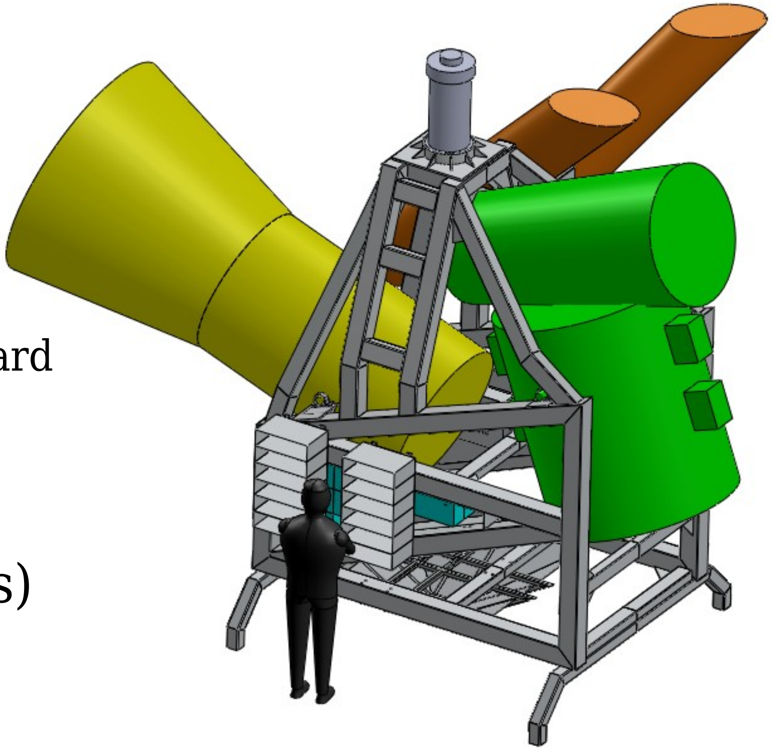
Science goal and performance

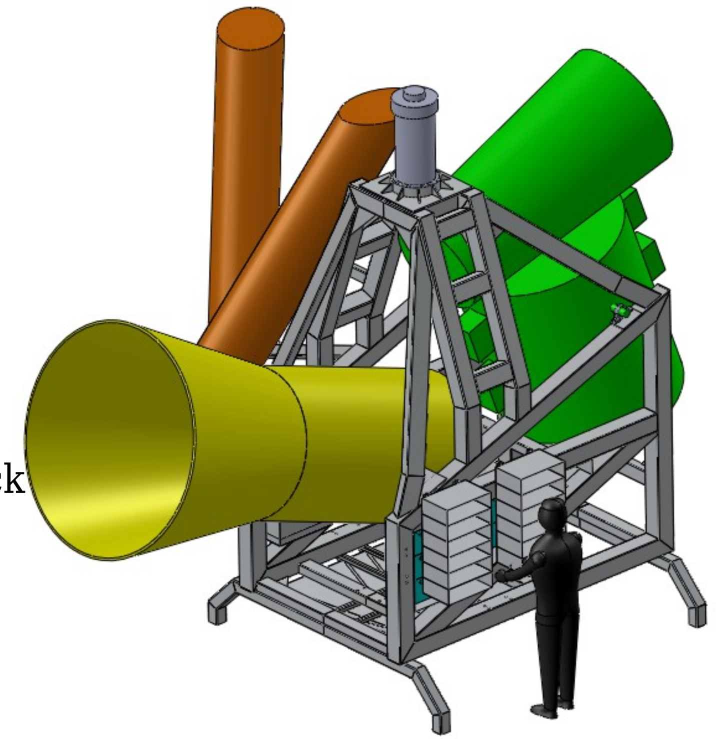
Francesco Piacentini (Univ. Roma La Sapienza) – for the LSPE collaboration

LSPE is a balloon payload aimed at:

- Measure large scale CMB polarization and temperature anisotropies
  - Explore large scales anomalies measured by Planck
- Constrain the B-modes of polarization
  - ell range [2-100]
- Improve the limit on tensor to scalar ratio **r**
  - **r =** 0.03, at 99.7% confidence
- Test and validate technologies for space application
  - Large Cold Achromatic Half Wave Plate (50 cm)
  - ESA ITT approved to G. Pisano (Manchester)

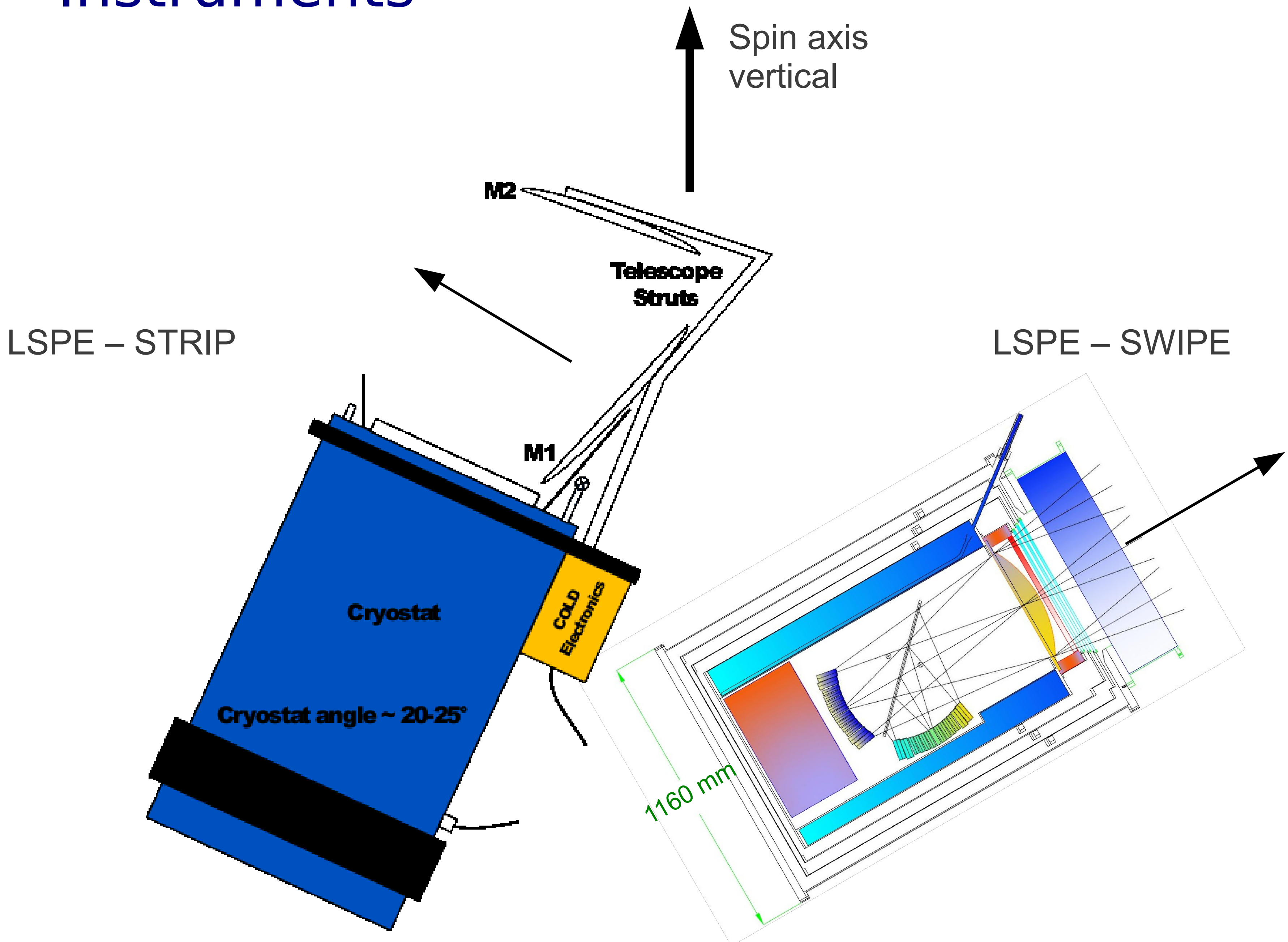
Payload – mission





- The Large-Scale Polarization Explorer is
  - a spinning stratospheric balloon payload
  - 15 days duration fight, North hemisphere, from Svalbard
  - in the polar night (700 W, on batteries)
  - using polarization modulators to achieve high stability
- Frequency coverage: 40 – 250 GHz (5 channels)
- Two instruments:
  - SWIPE (95, 145, 245 GHz):
    - Multimode large throughput horns
    - bolometers at 300 mK
    - Rotating, 4 K cold half wave plate + wire grid polarizer
  - STRIP (43, 90 GHz),
    - HEMT coherent polarimeters at 20 K,
    - same polarimeters as in QUIET
    - 49 modules at 43 GHz, 7 modules at 95 GHz for crosscheck of systematic effects
- Angular resolution: 1.5 – 2.3 deg FWHM
- Combined sensitivity: 10 uK arcmin per flight

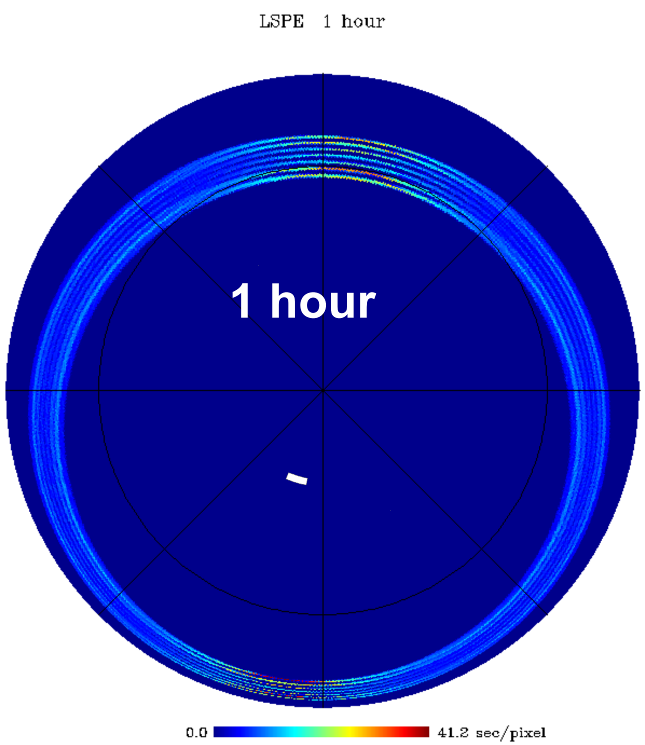
Instruments

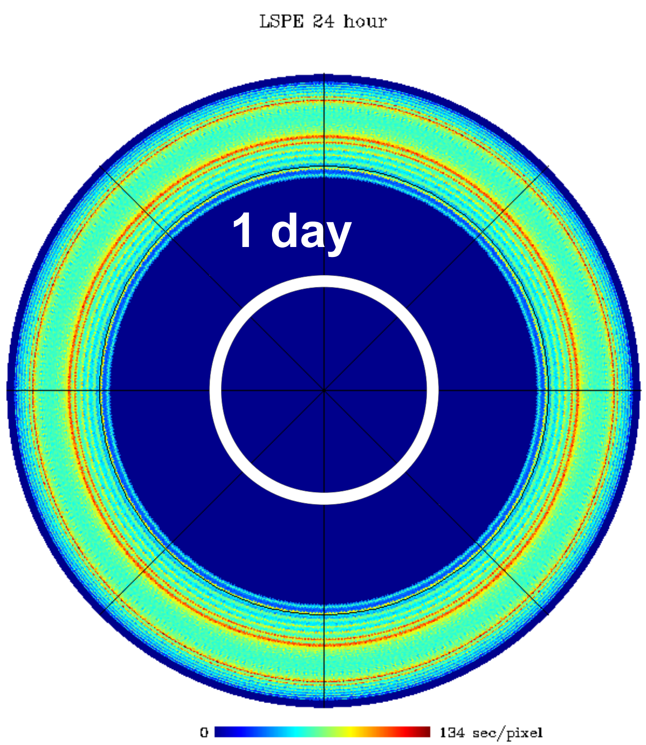


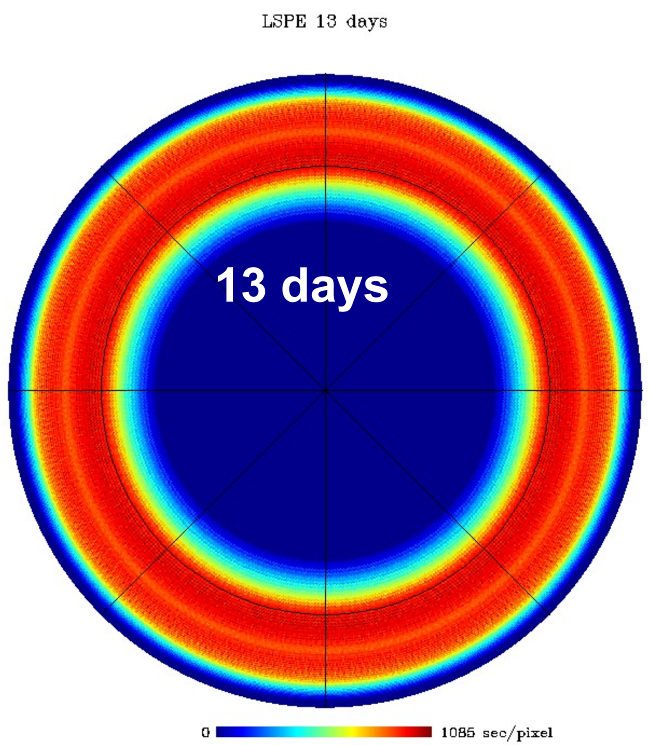
Instruments details are presented in a poster

Observation strategy

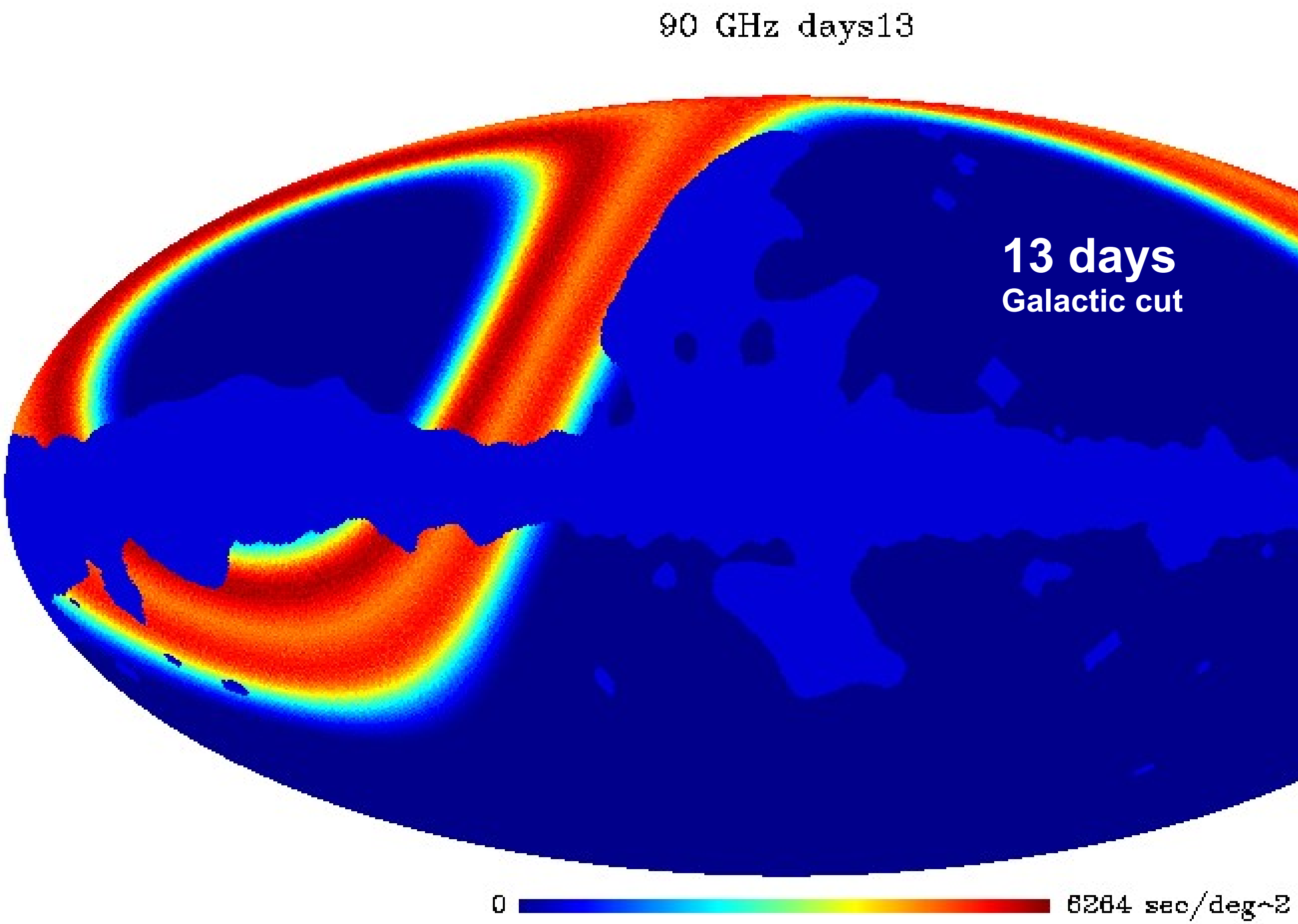
- Spin rate = 3 rpm
- Latitude = 78 N
- Longitude, variable
- Elevation range
  - independent for the two instruments
  - 30 – 40 degrees above horizon







Sky coverage



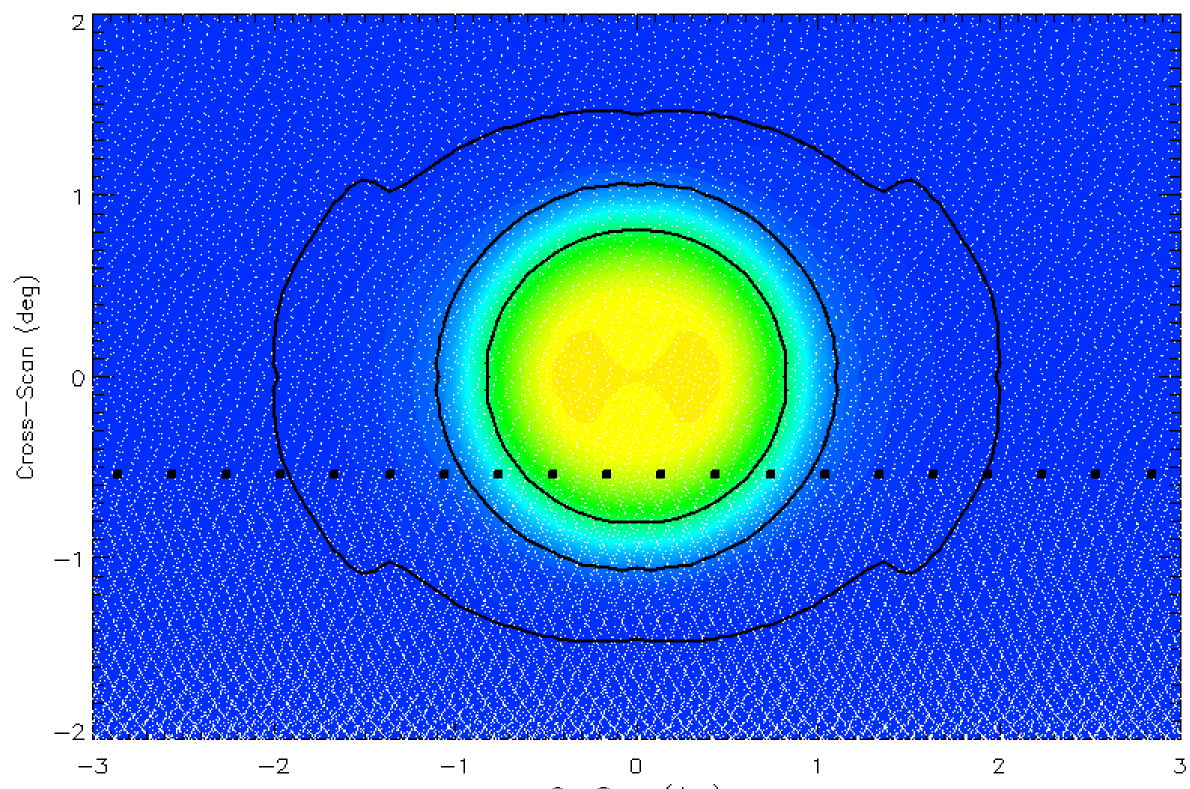
23% of the sky is observed using the WMAP polarization mask

The same sky is observed every day (depending on the elevation changes strategy)

Calibration

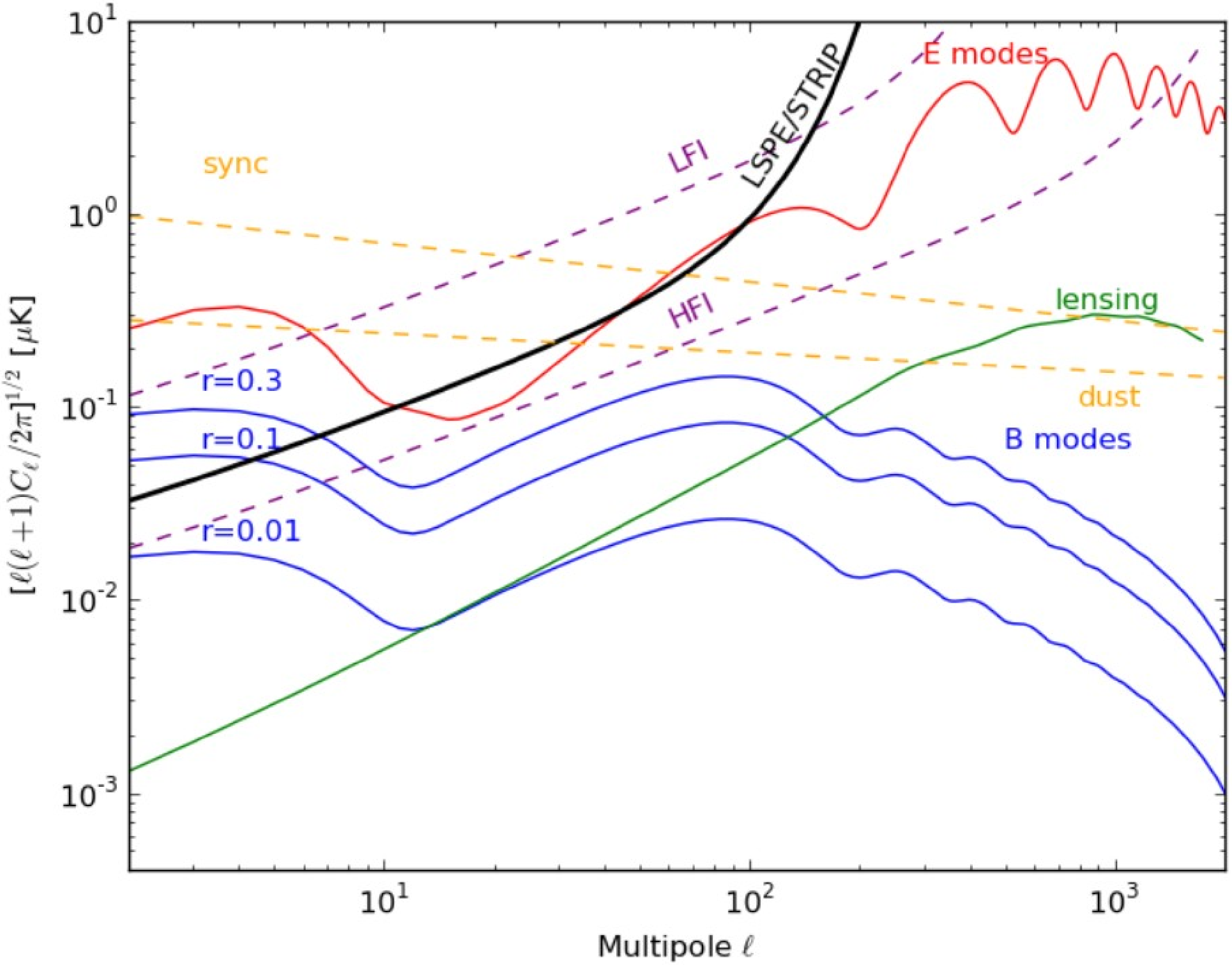
- Sources
  - S/N sampling at 60 Hz
  - Signal is intensity
  - S?N for one detector
- Polarization angle and efficiency
  - Crab
  - Moon limb
  - Ground based calibration
- Beam mapping
  - In black: one scan
  - In white: one day
    - More than 2000 samples per day
    - Increase S/N by ~45
    - Increase S/N by ~160 in 13 days

Source	Culmination (deg)	S/N per sample at 44 GHz	S/N per sample at 90 GHz	S/N per sample at 95 GHz	S/N per sample at 145 GHz	S/N per sample at 245 GHz
Moon	30	37500	200000	2000000	700000	2000000
Crab	34	20	18	22	23	28
Mars	0	0.30	1.6	2	5.6	18
Jupiter	27	15	80	100	275	850
Saturn	-6	1.4	7	9	24	70
Uranus	16	0.05	0.24	0.3	0.8	2.5



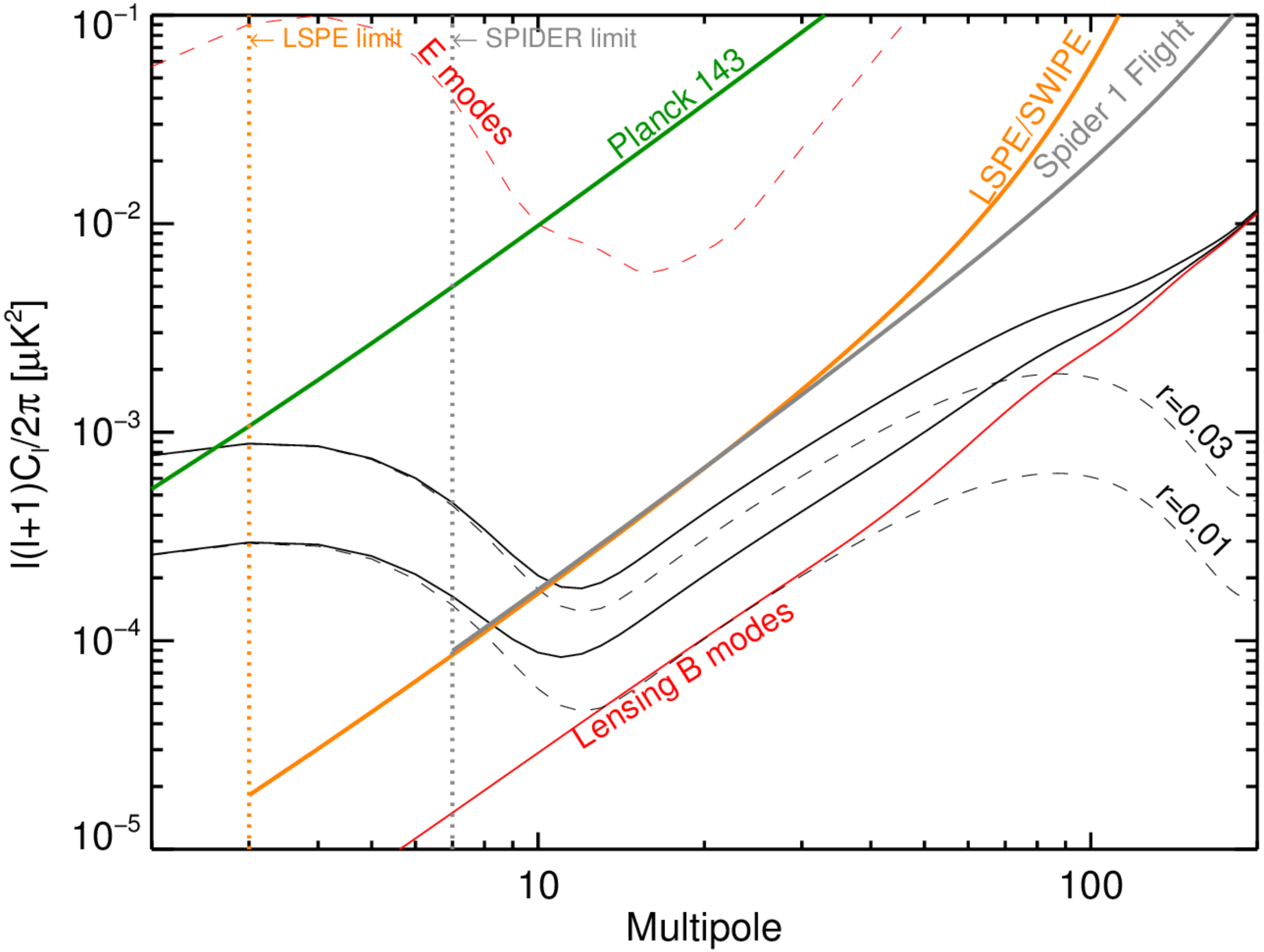
Expected performance – sensitivity

- STRIP – low frequency

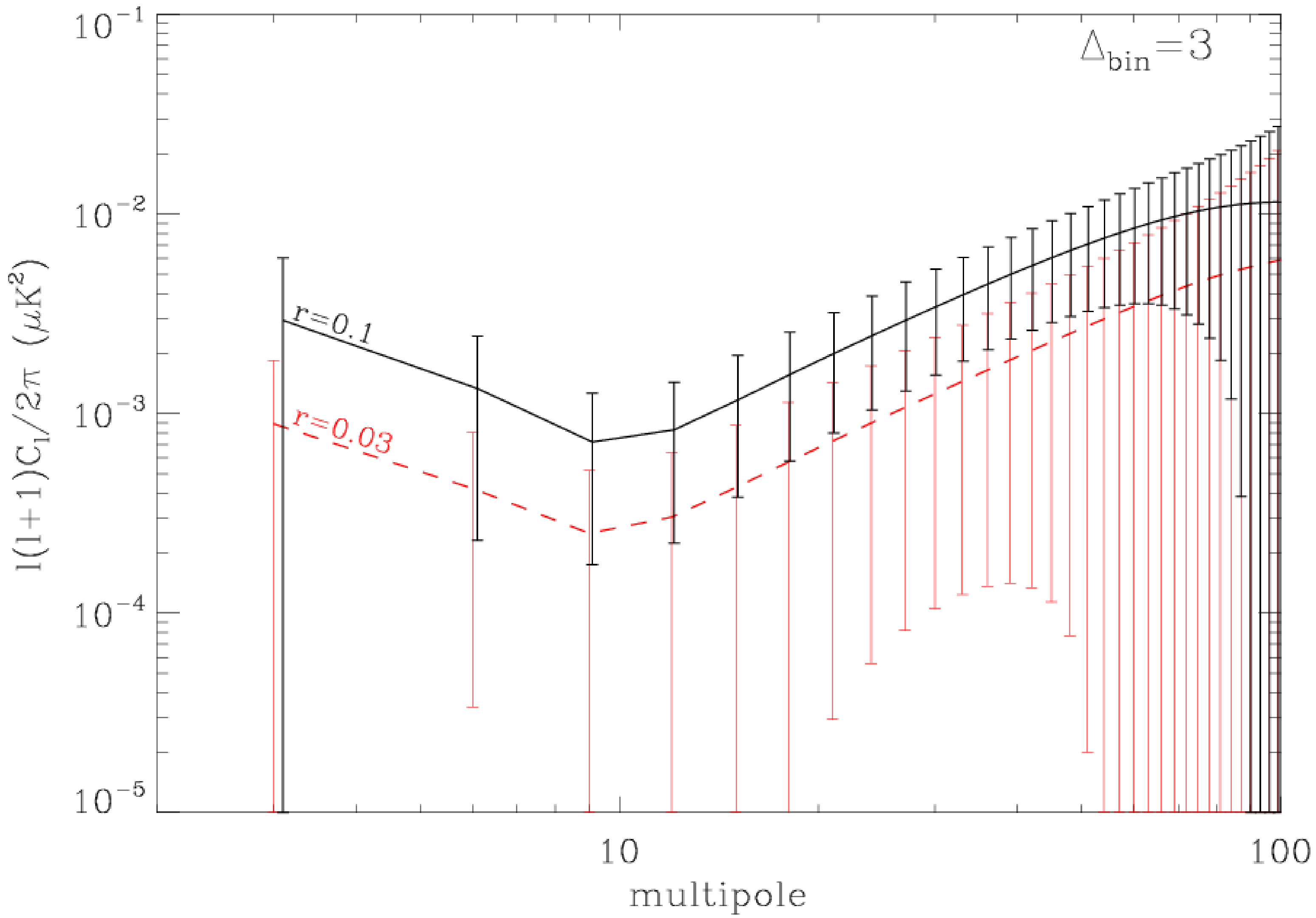


Expected performance – sensitivity

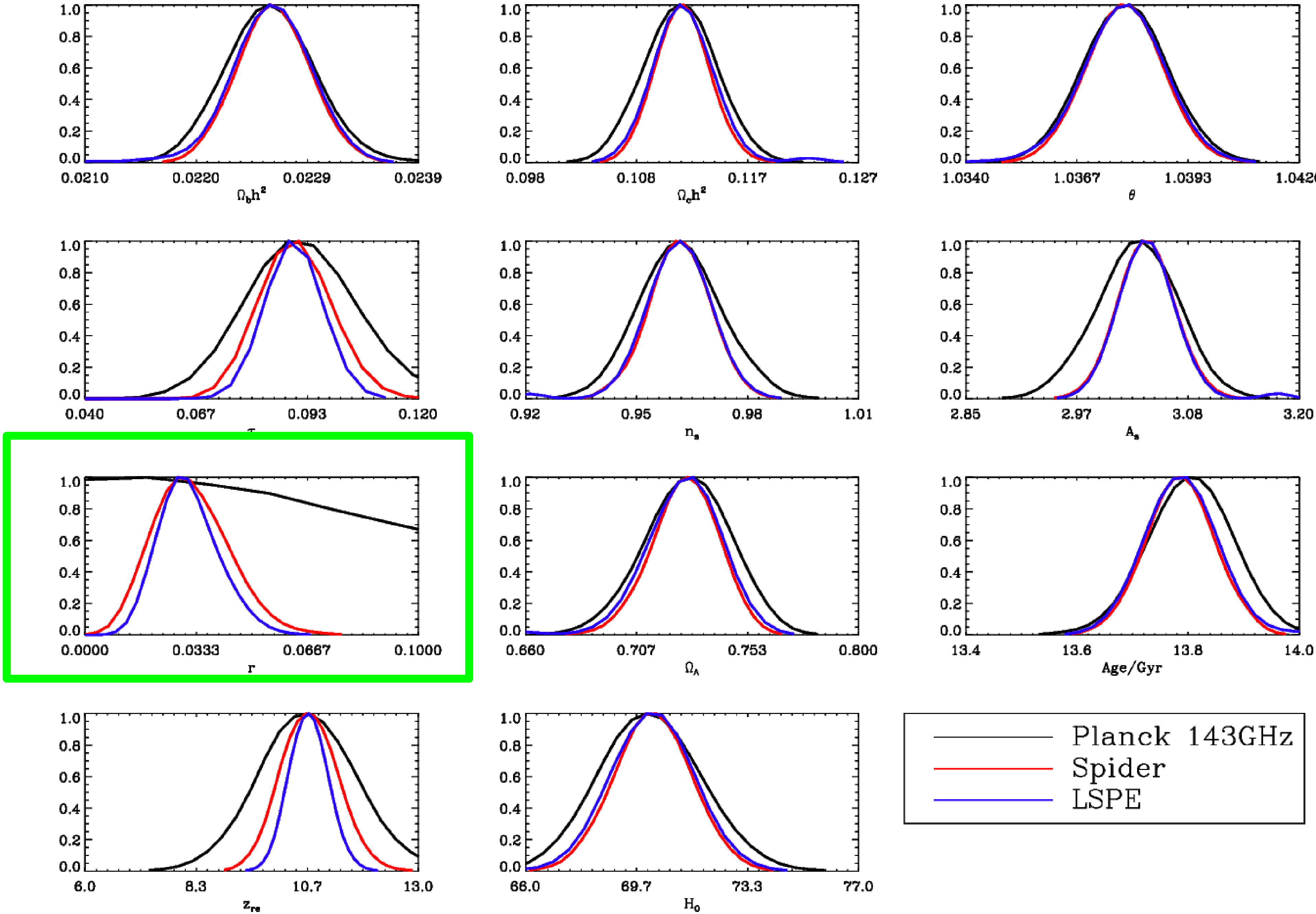
- SWIPE – high frequency



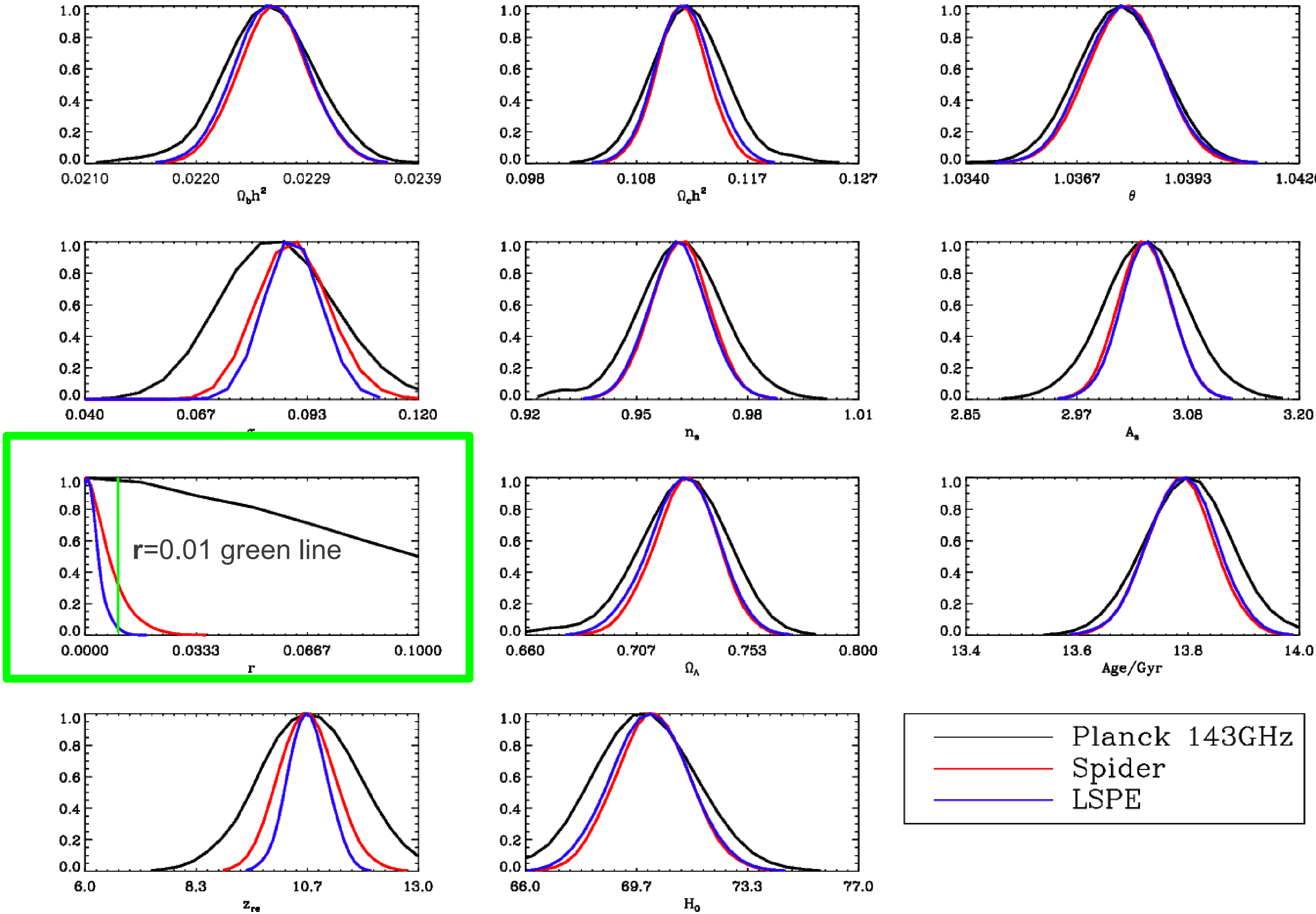
Sensitivity – BB power spectrum



Sensitivity – parameters (**r**=0.03)

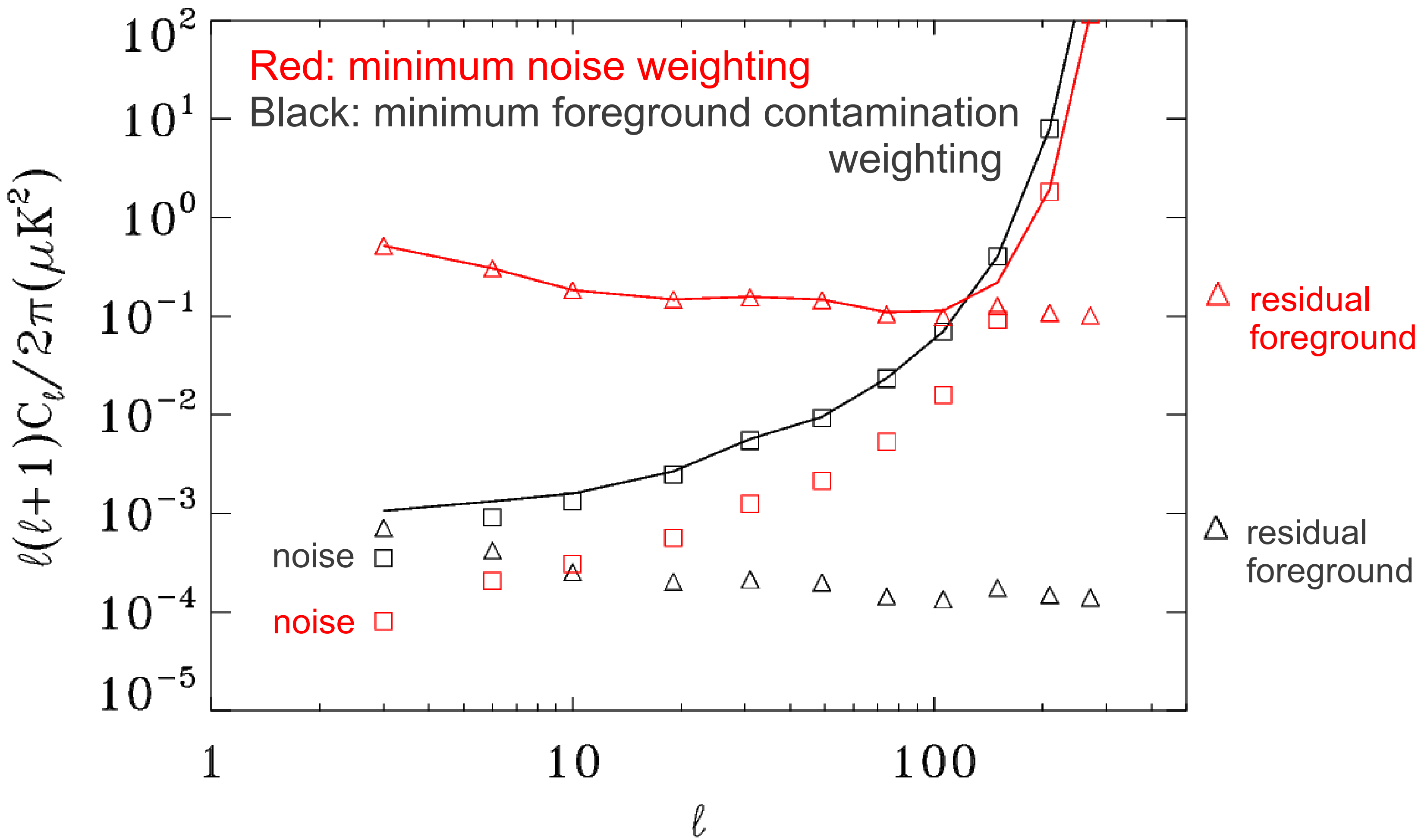


Sensitivity – parameters (**r**=0.001)



Component separation

- We plan to adopt a weighting scheme that minimizes foregrounds residuals
  - Bonaldi, A.; Ricciardi, S. 2011 MNRAS
  - Here is based on LSPE only. In combination with Planck can improve even more



Systematic effects

	Systematic effect	Mitigation
	All listed (except pointing)	**Combination of two instruments with 90 GHz channel**
Polarization	HWP emission	Scan with HWP steady, Low temperature HWP
	Wire grid emission, reflected by HWP	Low temperature WG, antireflection coating on HWP
	Differential transmission of HWP	Scan with HWP steady
	Differential reflection of HWP	Scan with HWP steady, antireflection coating on HWP
	Differential phase shift by HWP	Scan with HWP steady, Spectral bandwidth optimization
	Slant incidence of rays on HWP	Scan with HWP steady
	Cross polar leakage	Lab. Calibration
	Absolute polar angles calibration	Lab Calibration / Moon / Crab
	Thermal fluctuations of HWP	Scan with HWP steady, thermal link HWP – cryogen
Optics	Main beam uncertainty	Laboratory calibration / observation of planets
	Main beam ellipticity	Reduced in multimode system; lab. and flight calibration
	Sidelobes pickup of sky signal	Large shields, cold stop
	Sidelobes pickup of Earth and Balloon	Large shields, cold stop
Pointing	Pointing error	ACS Sensors
	Pendulation and atmospheric emission	Not polarized / orthogonal detectors
Detectors	Gain uncertainty	Calibration on anisotropy
	Gain stability	Calibration on anisotropy
	1/f noise	AC bias / T stabilization
	Correlated thermal drift	TES
	Non linearities	Compensation on scans

Half Wave Plate strategy: spin/step

- The HWP non-idealities such as:
  - Differential emission
  - Differential reflection
  - Differential phase shift
  - Slant incidence of radiation into HWP
  - Thermal fluctuations of HWP
- In the spinning case, this can generate a spurious signal,
  - angular dependent
  - With components at 4 times the angle
  - Systematic effect in the recovered polarization
- In the stepping case, this is step dependent offset
  - The offset is removed in any case
  - Signal modulation is provided by the scanning
  - Polarization is extracted by combing signals from the SAME detector at different time, with different HWP angles, same beam, same sidelobes
  - 1/f noise is treated by ML iterative mapmaking

Conclusion

- LSPE is exploring large scales, where Planck detected "anomalies"
- Night time polar balloon flight
- Designed for polarization purity
- Deep measure of polarized foreground
- Two 90 GHz channels with different technologies (HEMT, bolometers) for crosscheck of systematic effects
- Low frequency channel for optimal control of synchrotron polarized foregrounds
- Technology development for next generation space mission
- The **r**=0.03 at 99.7 confidence level is achievable
- Upper limit at **r**=0.01
- Timescale: launch on Winter 2014/15

Collaboration

- Dipartimento di Fisica, Sapienza Università di Roma, Italy
- Dipartimento di Fisica, Università degli Studi di Milano, Italy
- Dipartimento di Fisica, Università di Milano Bicocca, Italy
- IASF-INAF Via Gobetti 101, Bologna, Italy
- IASF-INAF, Milano, Italy
- OAT-INAF, Trieste, Italy
- Physics Department, University of Trieste, Italy
- IFAC-CNR, Firenze, Italy
- Dip. Meccanica e Tecnologie Industriali, Univ. di Firenze, Italy
- Cavendish Laboratory, University of Cambridge, UK
- Jodrell Bank Centre for Astrophysics, University of Manchester, UK
- IEIIT-CNR, Torino, Italy
- Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy
- Agenzia Spaziale Italiana, Roma, Italy

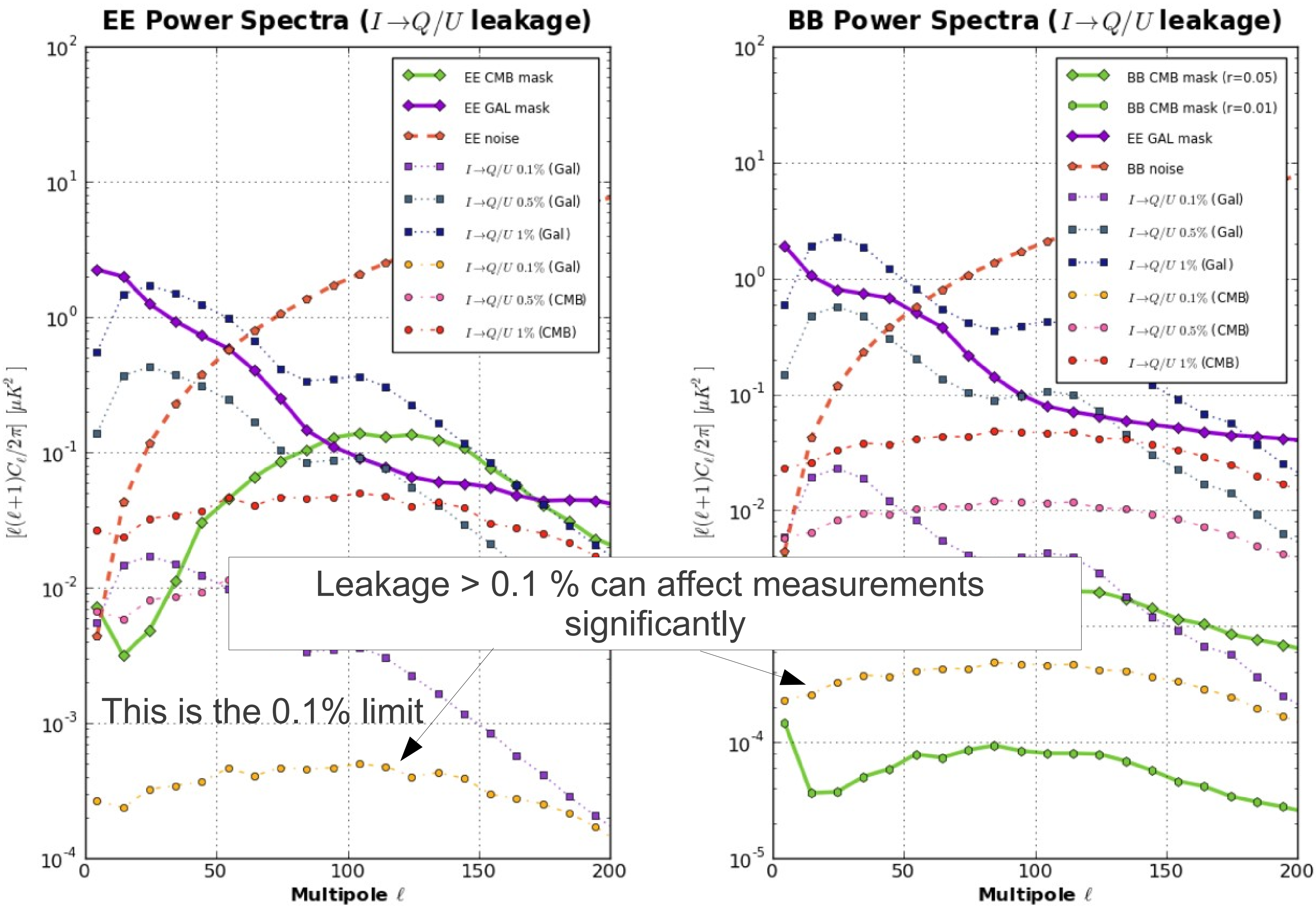
References

- The LSPE collaboration et al., *The Large-Scale Polarization Explorer (LSPE)*, Proc. SPIE 8446, Ground-based and Airborne Instrumentation for Astronomy IV, 84467A (September 24, 2012)
- Bersanelli, M. et al., *A coherent polarimeter array for the Large Scale Polarization Explorer (LSPE) balloon experiment*, Proc. SPIE 8446, Ground-based and Airborne Instrumentation for Astronomy IV, 84467C (September 24, 2012)
- de Bernardis P. et al, *SWIPE: a bolometric polarimeter for the Large-Scale Polarization Explorer*, Proc. SPIE 8446, Ground-based and Airborne Instrumentation for Astronomy IV, 84467C (September 24, 2012)

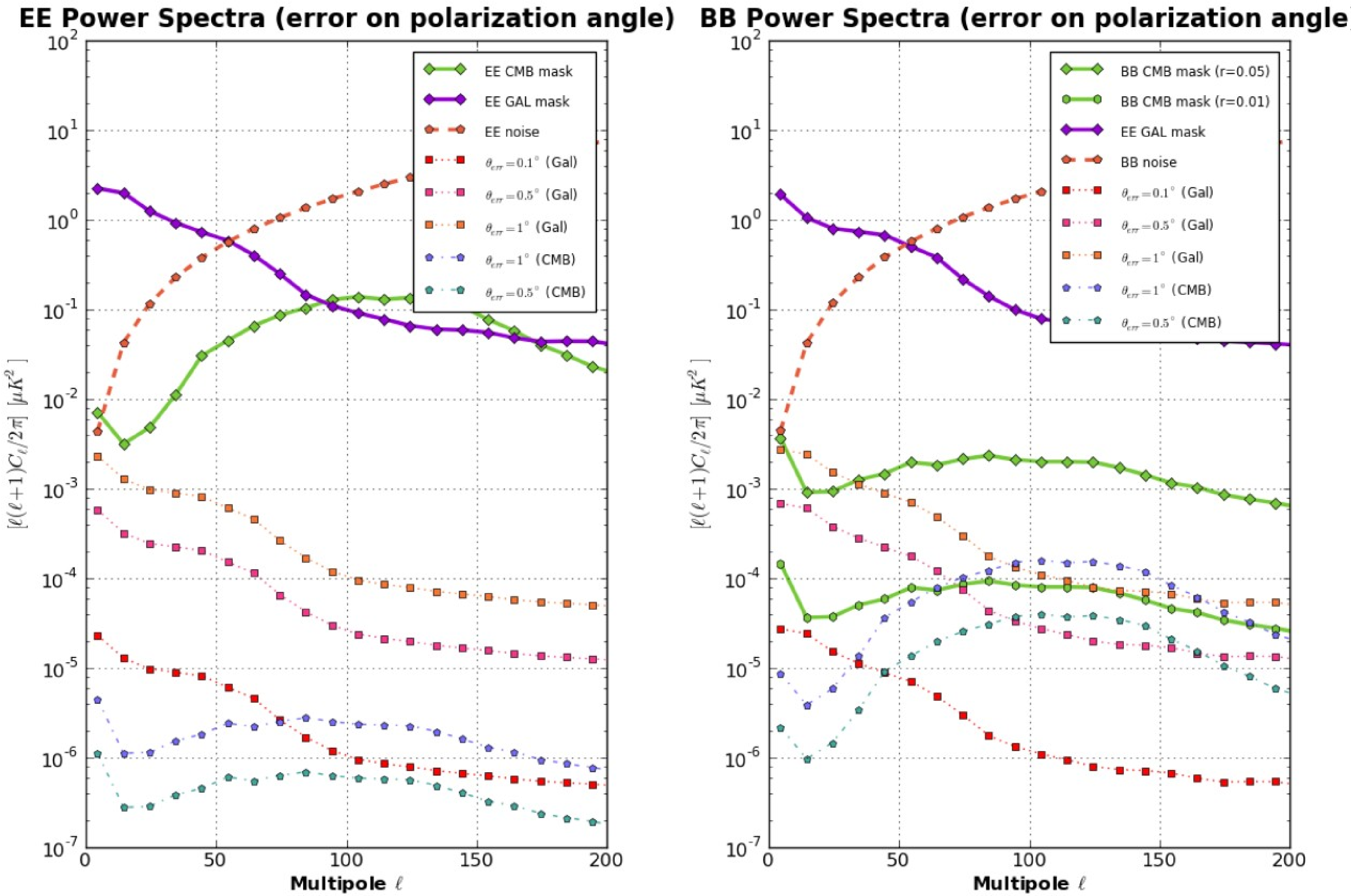
Half Wave Plate for SWIPE

- Similar to what in: G. Pisano, M. W. Ng, V. C. Haynes, and B. Maffei, "*A BROADBAND METAL-MESH HALF-WAVE PLATE FOR MILLIMETRE WAVE LINEAR POLARISATION ROTATION*", Progress In Electromagnetics Research M, Vol. 25, 101–114, 2012
- Dielectric embedded metal mesh
- Metallic grids with sub-wavelength anisotropic geometries able to mimic the behaviour of natural birefringent materials
- The current mesh HWP has measured performance, across a 20% bandwidth (78-100 GHz)
  - Transmission 0.9
  - differential phase-shift flatness and 180.4 ± 2.9 degrees
  - Cross-polarisation -35 dB
- ESA ITT grant to G. Pisano (Manchester) for large prototype development

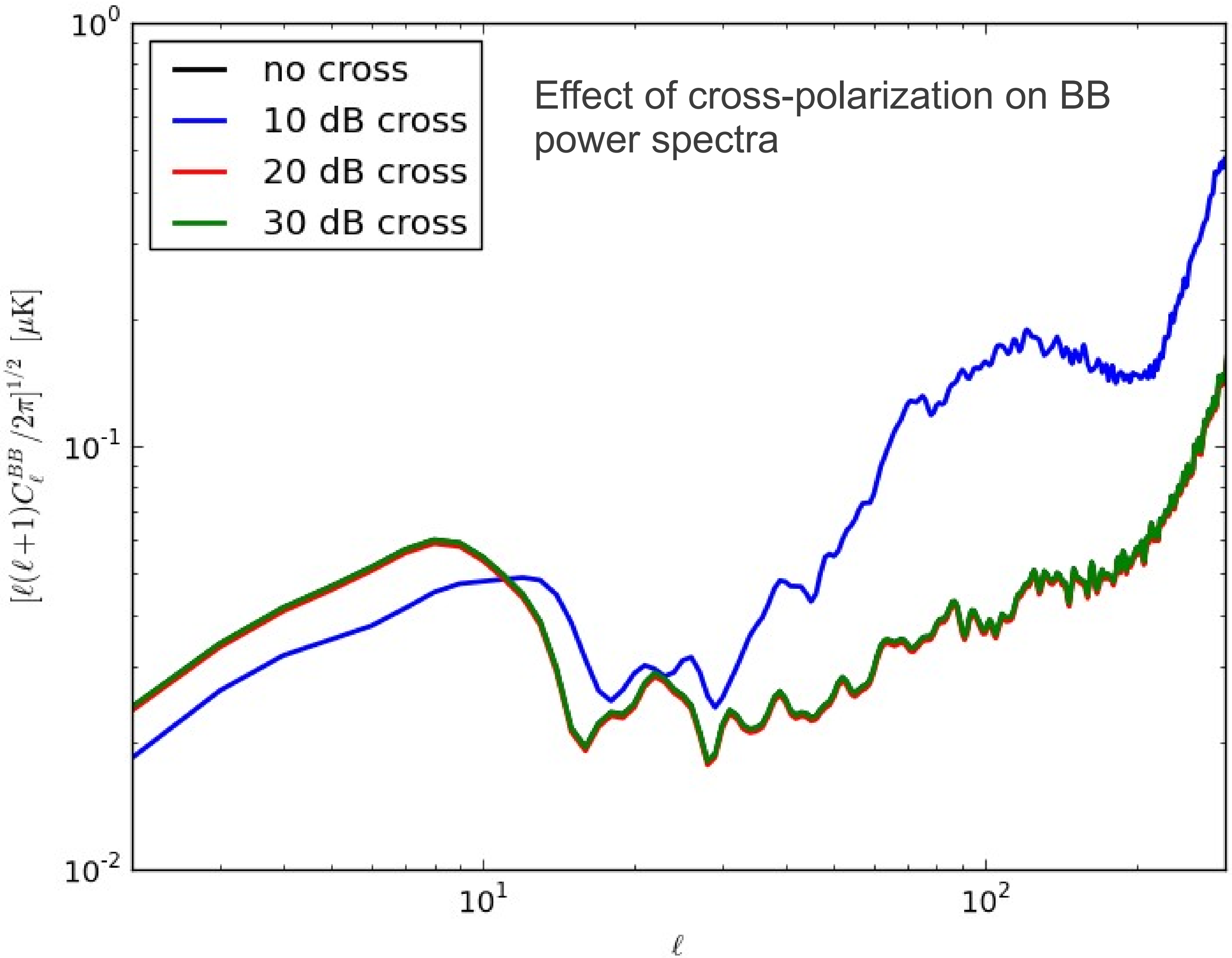
STRIP-43 GHz – effect of I → Q/U leakage



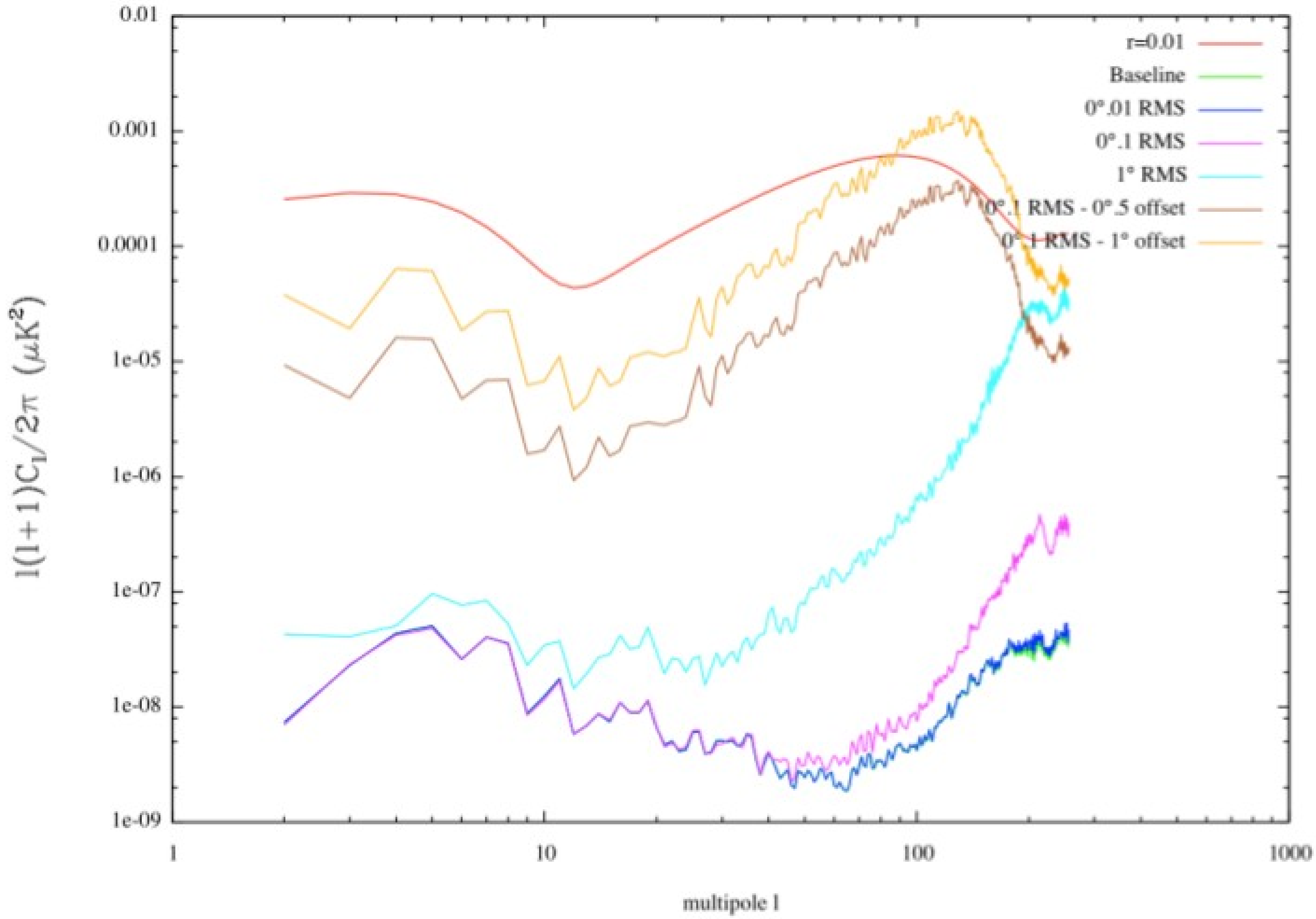
STRIP-43 GHz – effect of polarization angle uncertainty



STRIP-43 GHz – effect of cross-polarization



SWIPE – polar angle



SWIPE – HWP phase shift error